Software Bill of Materials and Supply Chain with the Yocto Project

Joshua Watt

Embedded Linux Conference

June 23, 2022

About Me

- Worked at Garmin since 2009
- Using OpenEmbedded & Yocto Project since 2016
- Member of the OpenEmbedded Technical Steering Committee (TSC)
- Joshua.Watt@garmin.com
- JPEWhacker@gmail.com
- IRC (OFTC or libera): JPEW
- Twitter: @JPEW_dev
- LinkedIn: joshua-watt-dev

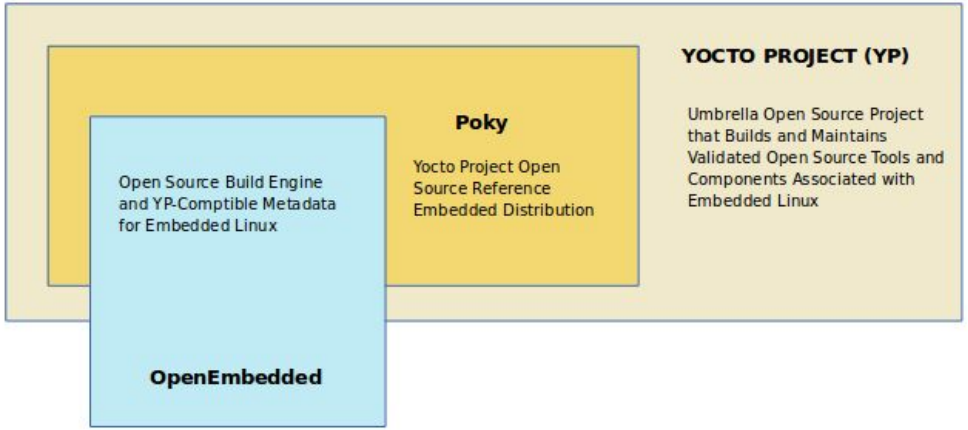
Yocto Project and OpenEmbedded

OpenEmbedded

- Community project
- OpenEmbedded core layer
- Build system (bitbake)

Yocto Project

- Linux Foundation project
- Poky reference distribution
- Runs QA tests
- Manages release schedule
- Provides funding for personnel
- Documentation



Outline

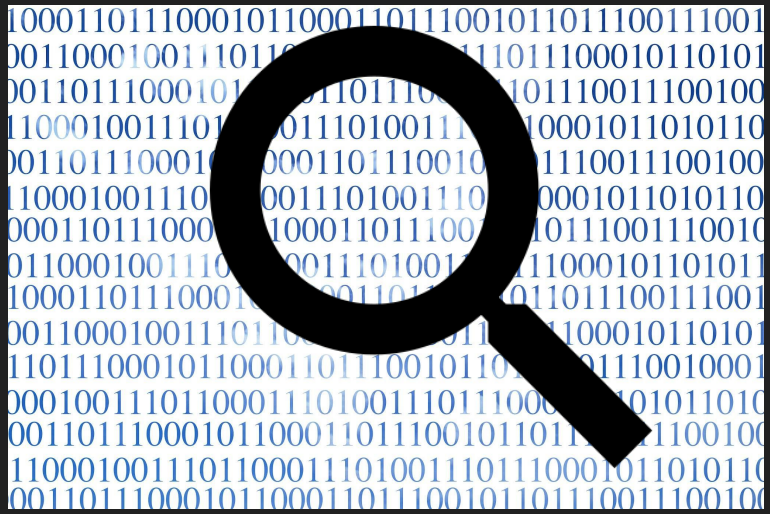
- Software Supply Chain
- OpenEmbedded Build Flow
- Software Bill of Materials
- SPDX Contents
- Reproducible Builds
- Buildtools Tarball

Software Supply Chain

Why is the Software Supply Chain Important?

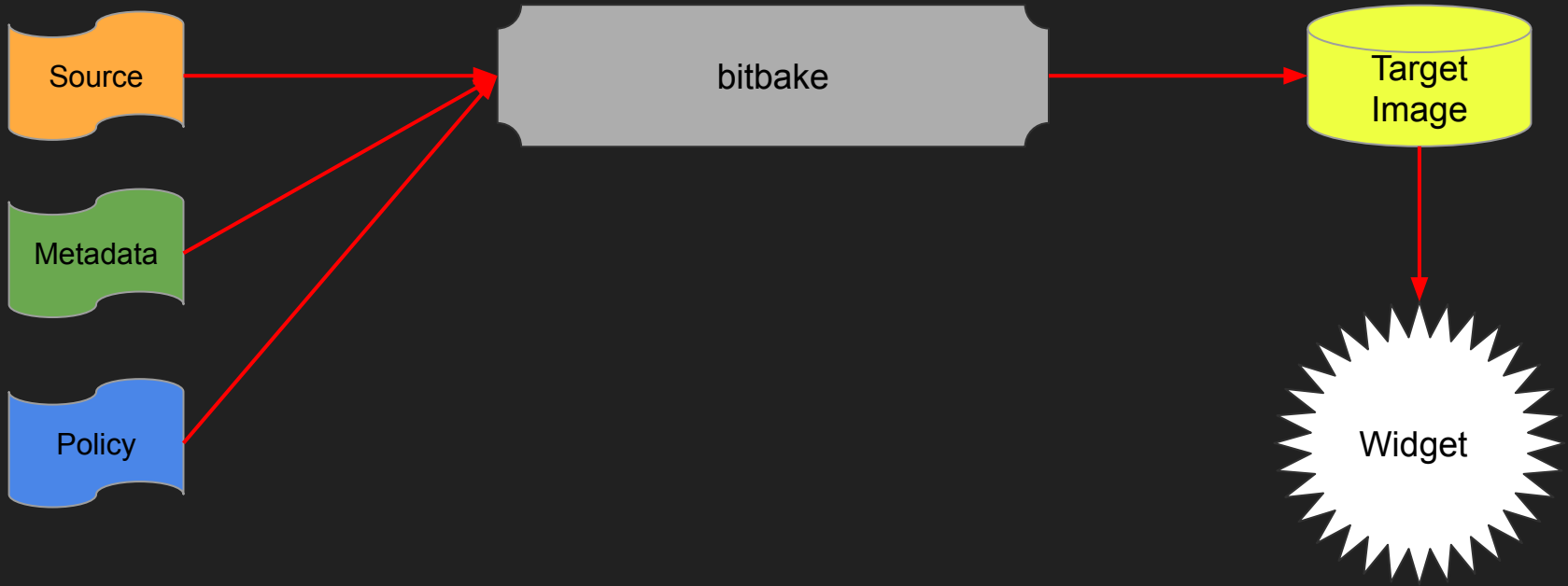
- What's in my Software?
  - Where did it come from?
  - What version is it?
- Am I complying with Software Licenses?
- Has it been tampered with?
- Is it vulnerable to exploits?
- **Can deliverables be traced back to their code?**

What's really in here?

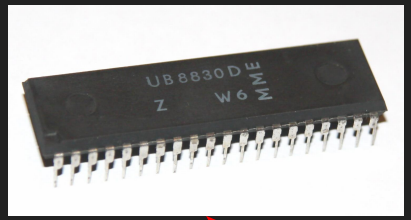


OpenEmbedded Build Flow

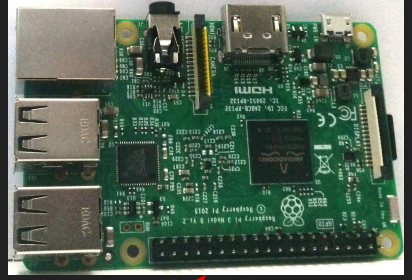
Build Images from Source Code



Images



Procolotor, CC BY 3.0 via Wikimedia Commons



QEMU

Target Image

SDK

eSDK

buildtools

IPK

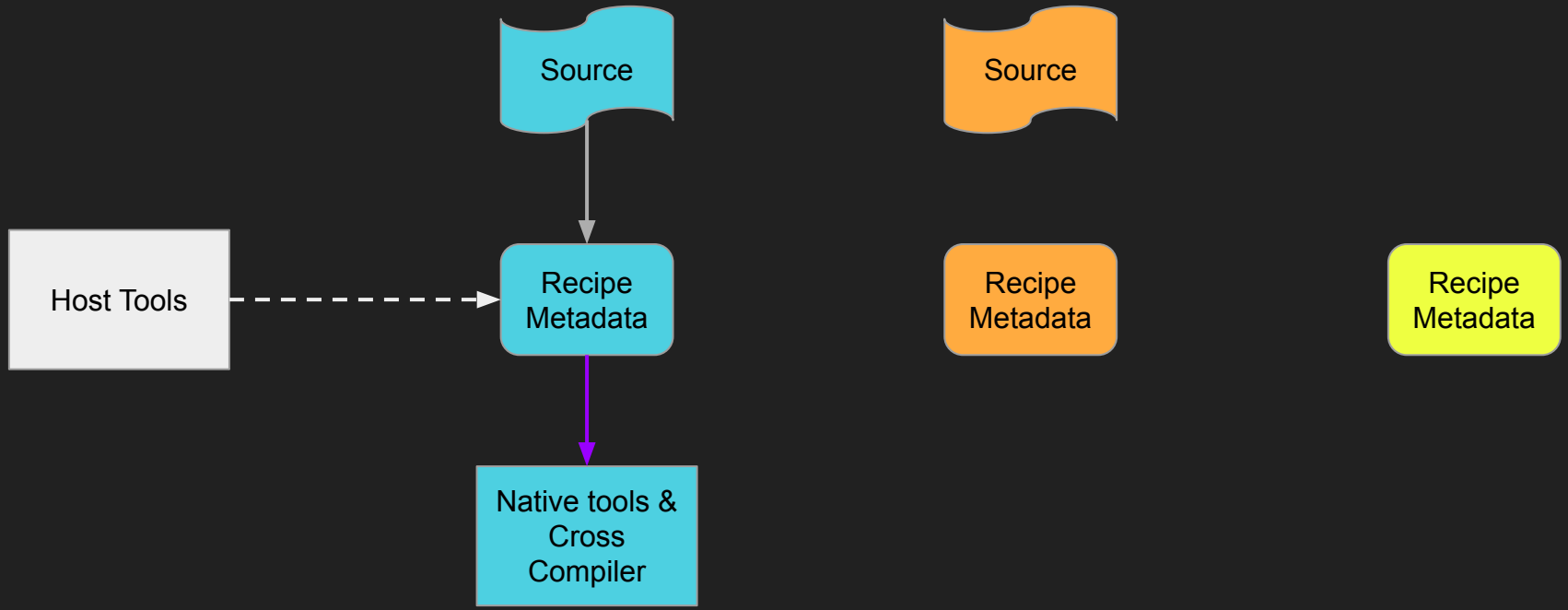
DEB

RPM

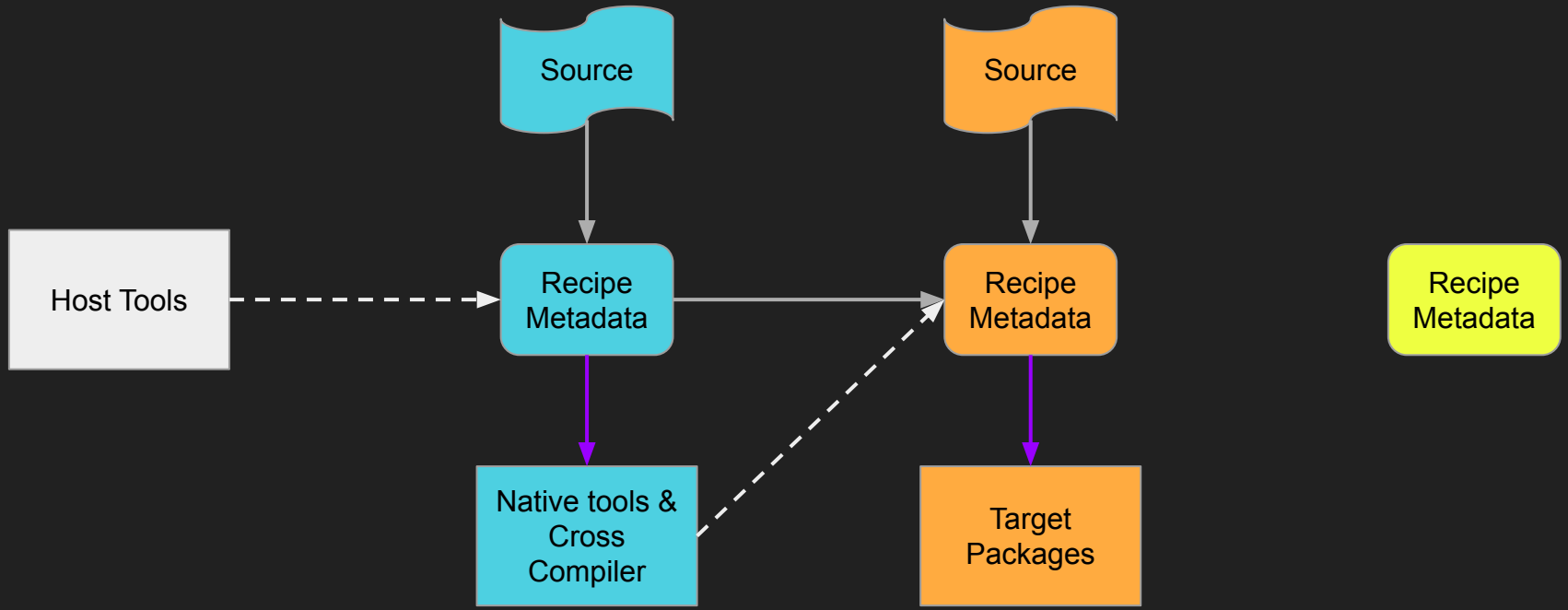
OPEN CONTAINER INITIATIVE

Simplified Build Flow

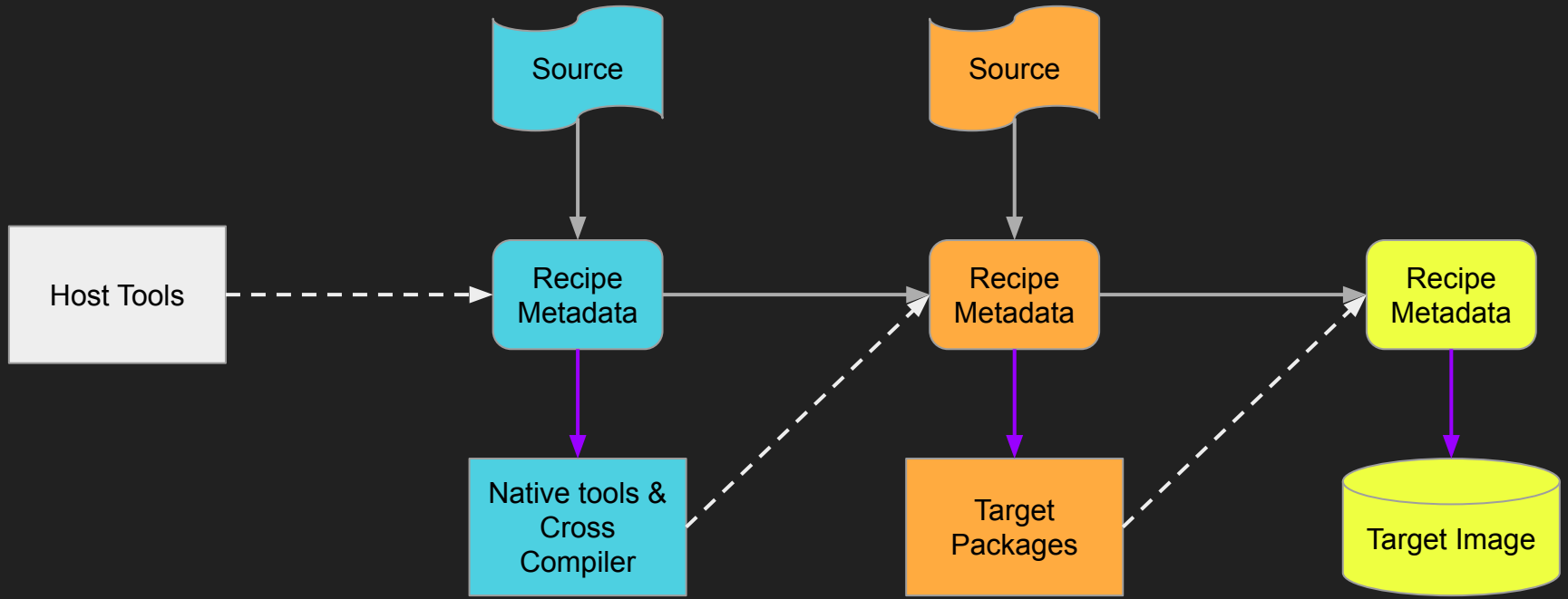
Simplified Build Flow



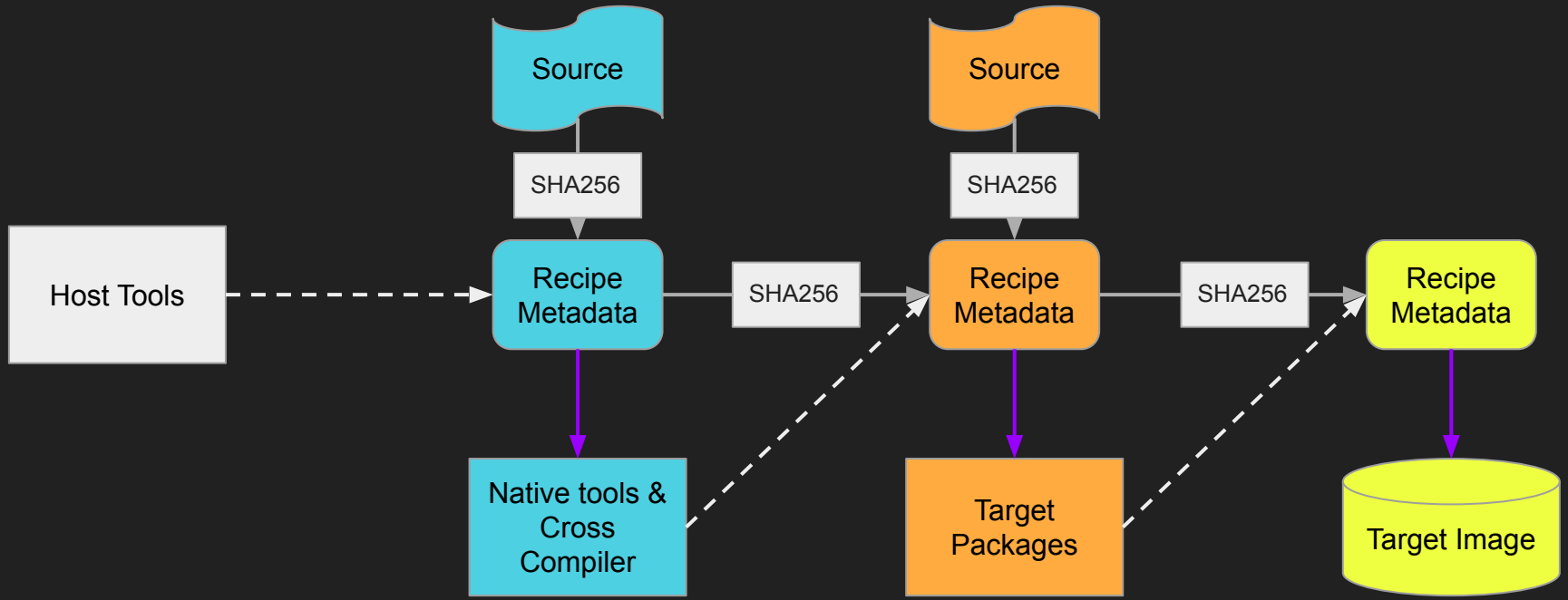
Simplified Build Flow



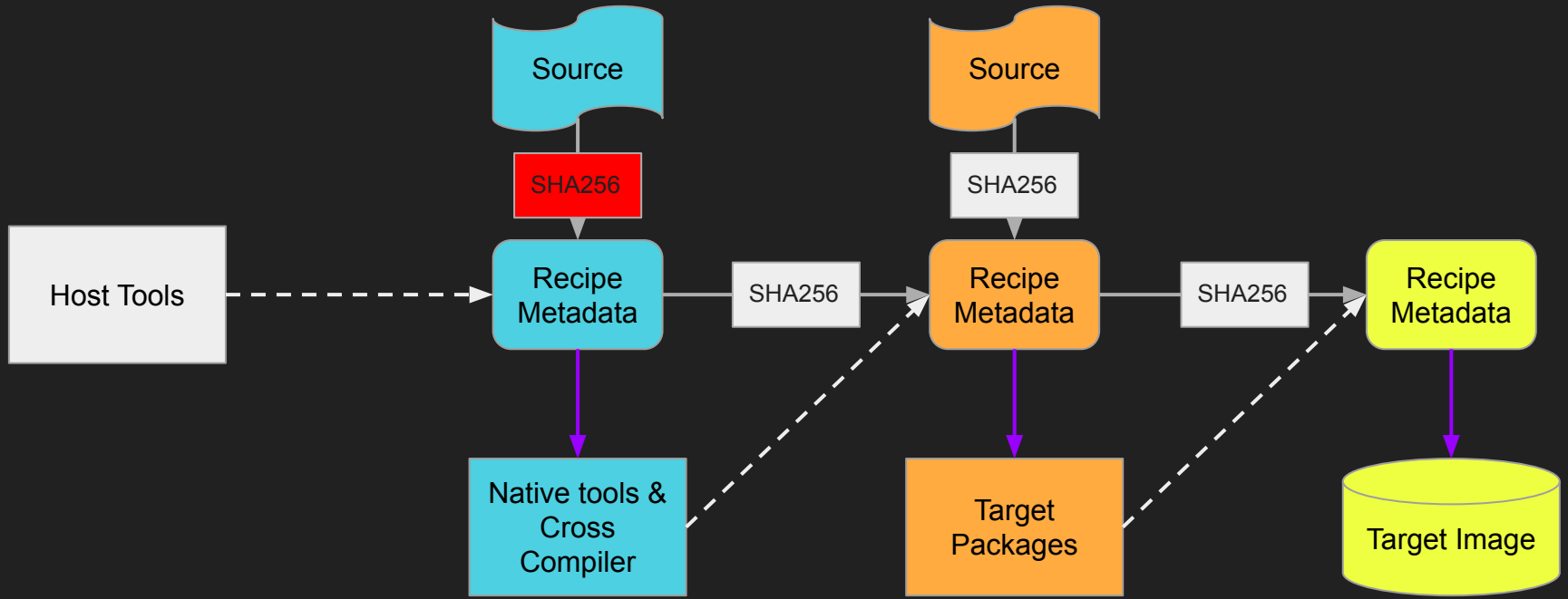
Simplified Build Flow



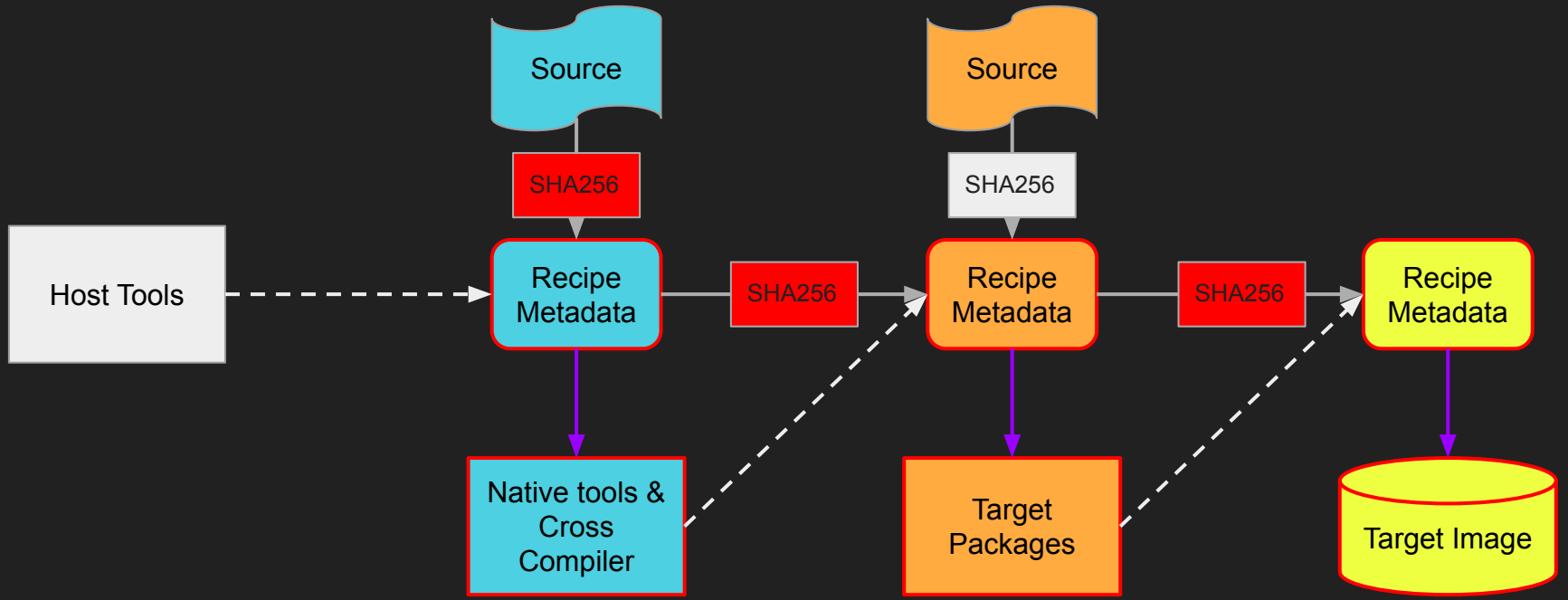
Simplified Build Flow



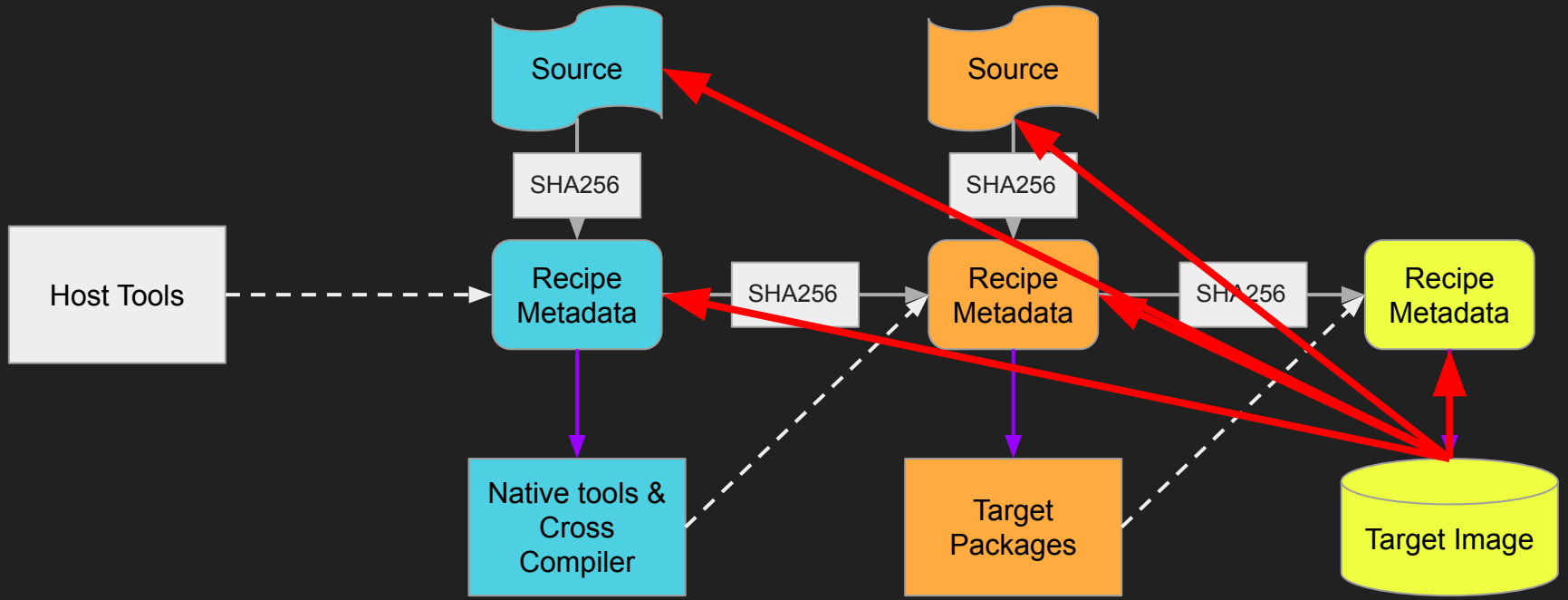
Simplified Build Flow



Simplified Build Flow



Simplified Build Flow



Traces the target image back to the code (and metadata)

Software Bill of Materials

"Nutrition Information" for Software

Ingredients: bash, Linux, u-boot, sshd, openssl, busybox

SBoM Facts

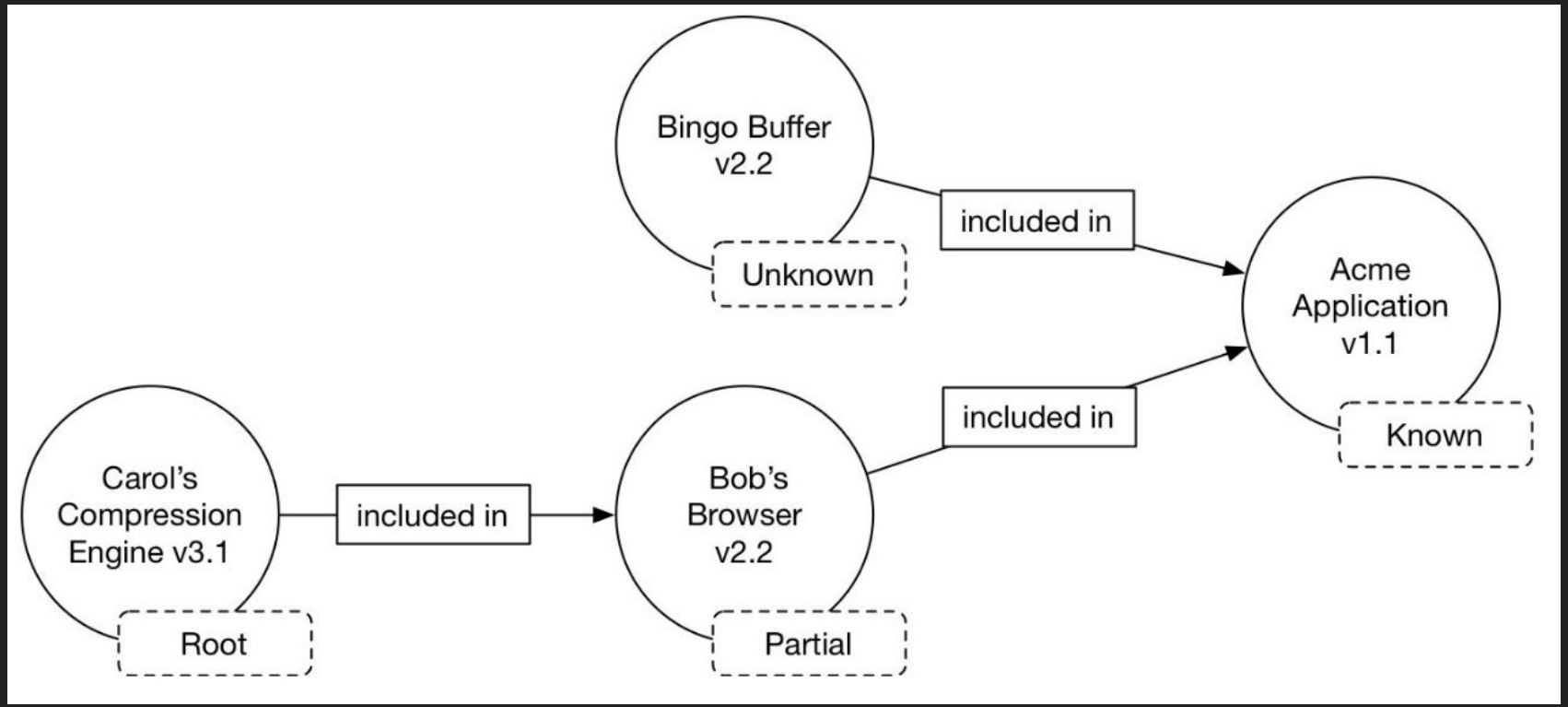
1 Serving per Device

Serving Size	**1**
CVEs Patched	**2**
CVE-2019-18276	
CVE-2014-0160	
Patches Applied	**30**

An SBoM is a method of describing the information about a Software Supply Chain using a standardized encoding that allows for easy exchange of data

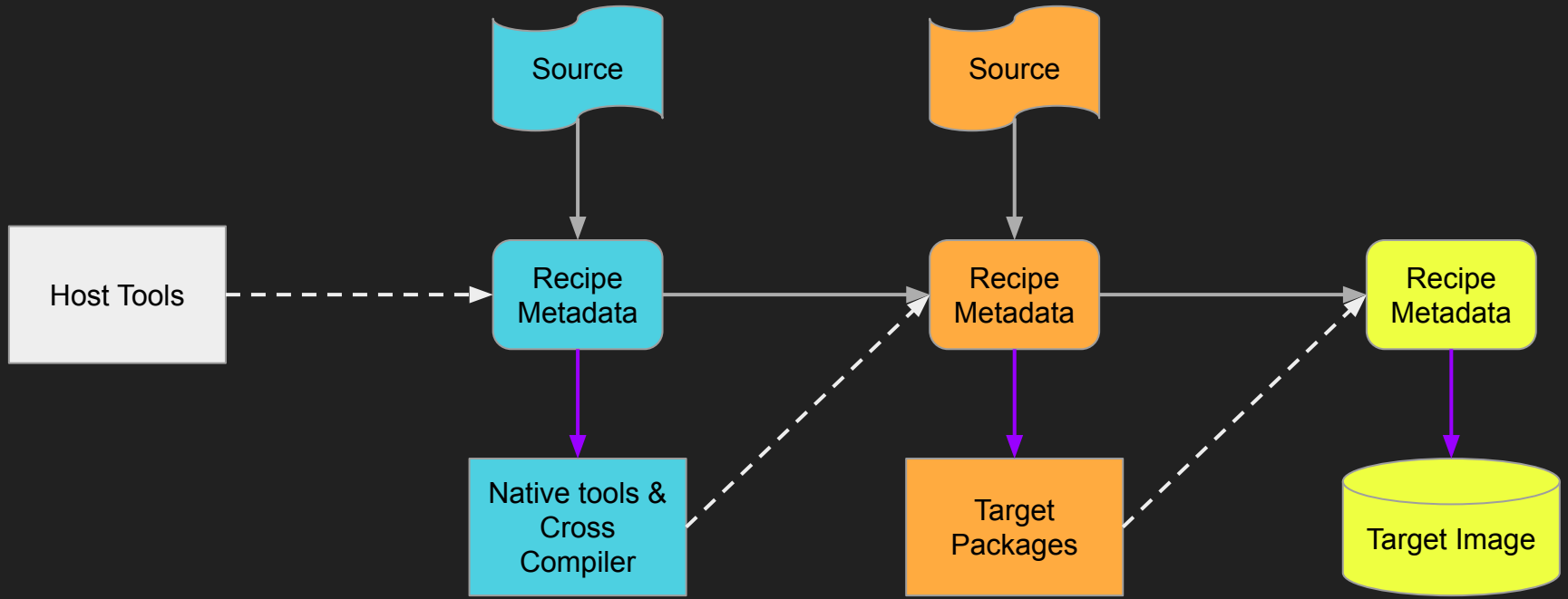
Multiple different SBoM formats may describe the same Software Supply Chain

What is an SBoM?

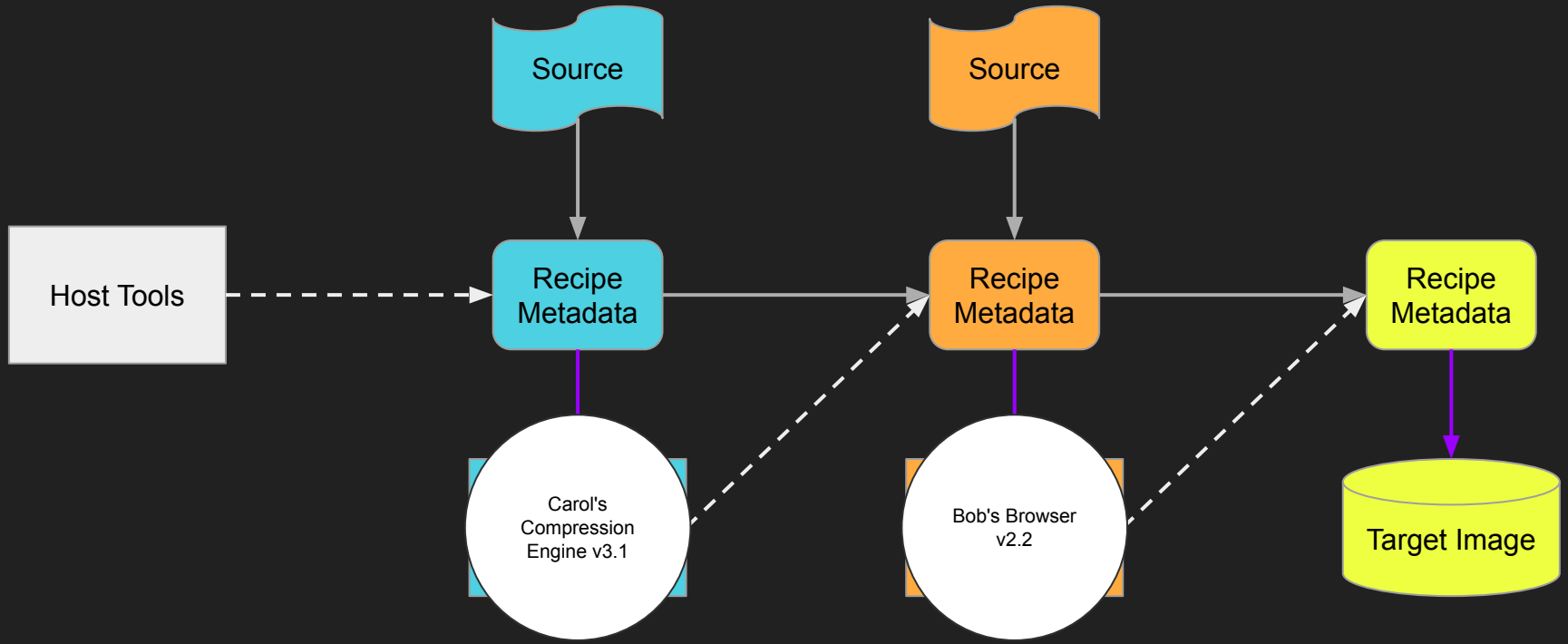


Source: NTIA's Framing Software Component Transparency: Establishing a Common Software Bill of Material (SBOM)

Simplified Build Flow



Simplified Build Flow



Recipe Metadata

Recipes already contain much of the data desired in a SBoM

- Version
- Source code URL
- Licenses
- Build time dependencies
- Run time dependencies
- CVEs patched
- Source Files
- Package Files
- …

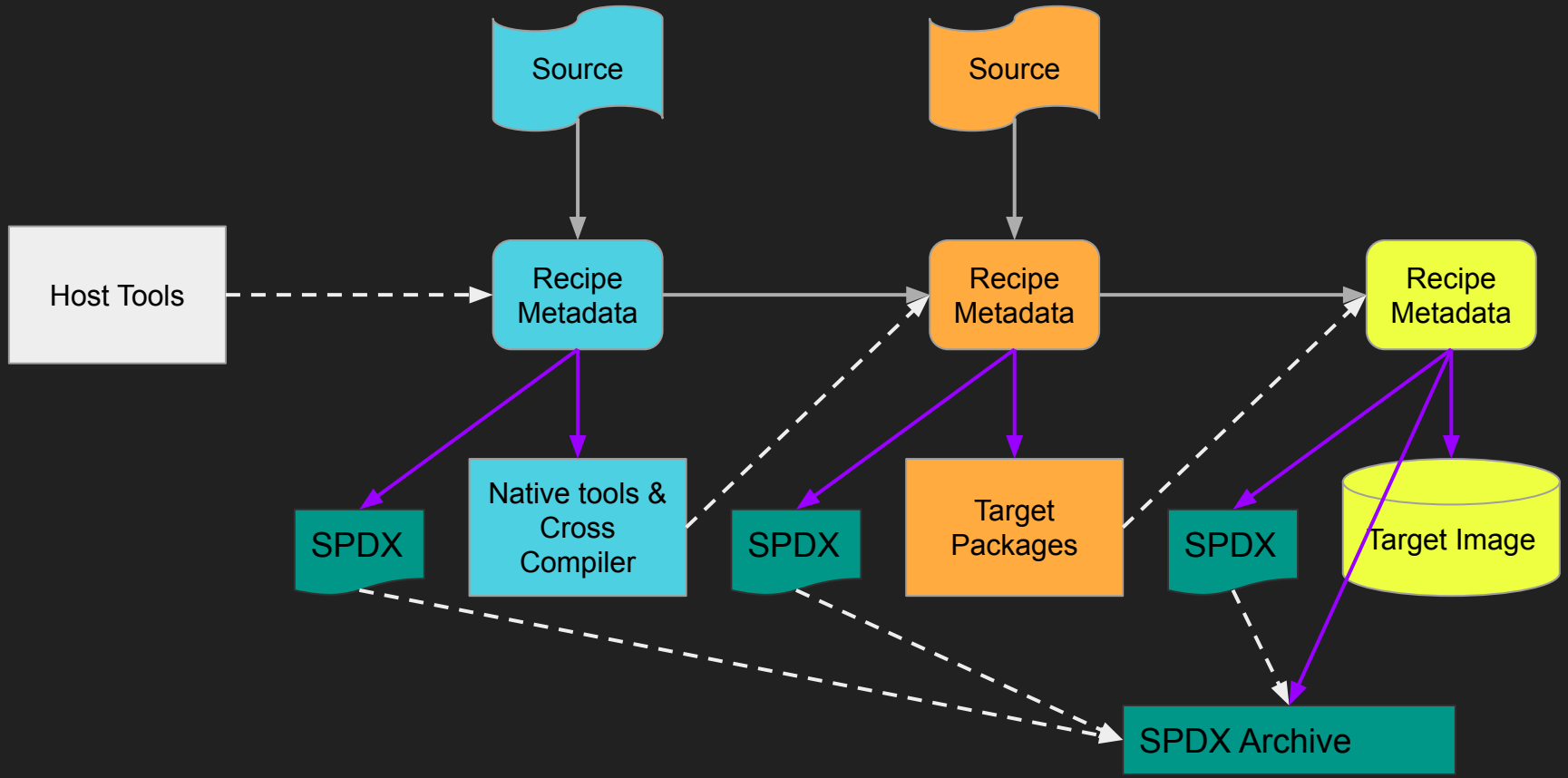
All of this information is authoritative (no guessing)

Generating SBoMs

OpenEmbedded has support for generating SBoMs in SPDX JSON format:

```
$ . oe-init-build-env
$ echo 'INHERIT += "create-spdx"' >> conf/local.conf
$ bitbake core-image-minimal
```

SPDX Generation



Yocto SPDX Features

- Declared License
  - With License Text if not a known SPDX license
- Homepage URL
- Download URL(s)
- CVEs fixed
- CPE
- Summary
- Description
- Source File Listing with Checksums
- Source file SPDX licenses
- Packages
- Package files with Checksums
- Package file GENERATED_FROM (from debug data)
- Build time dependencies
- Runtime dependencies
- Source code archive for analysis by other tools (e.g. Fossology)

What can we generate SPDX documents for?

TL; DR - Anything we can build

- "On target" C/C++/Fortran etc. ✅
- "native" build tools & cross compiler ✅
- Linux Kernel ✅
- Target images ✅
- SDKs ✅
- Container Images ✅
- VM Images ✅
- Rust 🚧
- Go 🚧

Configuration Knobs

- `SPDX_INCLUDE_SOURCES = "1"`
  - Includes patched source files from "`S`" in Recipe SPDX with a "`CONTAINS`" relationship
  - Off by default because the SPDX is *huge* when turned on
- `SPDX_ARCHIVE_SOURCES = "1"`
  - Creates a tarball of the sources, useful for running against other tools (e.g. fossology)
  - Off by default
- `SPDX_ARCHIVE_PACKAGED = "1"`
  - Creates a tarball of the packaged output files, useful for running against other tools
  - Off by default
- `SPDX_PRETTY = "1"`
  - Make output more human readable (master branch only)

Publishing Results on the Internet

- Set:
  - `SPDX_SUPPLIER = "Organization: My Company"` (1)
  - `SPDX_NAMESPACE_PREFIX = "http://my.company.com/spdx/"` (2)
  - `SPDX_UUID_NAMESPACE = "my.company.com"`

[1]: https://spdx.github.io/spdx-spec/package-information/#75-package-supplier-field
[2]: https://spdx.github.io/spdx-spec/document-creation-information/#65-spdx-document-namespace-field

SPDX Contents

Generated SPDX Files

```
$ ls -l tmp/deploy/images/qemux86-64/*.spdx.*
    core-image-minimal-qemux86-64.spdx.json
    core-image-minimal-qemux86-64.spdx.tar.zst
    core-image-minimal-qemux86-64.spdx.index.json
```

Generated SPDX Files

```
$ ls -l tmp/deploy/images/qemux86-64/*.spdx.*
    core-image-minimal-qemux86-64.spdx.json
    core-image-minimal-qemux86-64.spdx.tar.zst
    core-image-minimal-qemux86-64.spdx.index.json
```

The SPDX JSON file for the image itself

Generated SPDX Files

```
$ ls -l tmp/deploy/images/qemux86-64/*.spdx.*
    core-image-minimal-qemux86-64.spdx.json
    core-image-minimal-qemux86-64.spdx.tar.zst
    core-image-minimal-qemux86-64.spdx.index.json
```

Compressed Tarball containing all of the SPDX documents for the image itself, all packages that were installed in the image, all recipes that generated those packages, and the index file.

Generated SPDX Files

```
$ ls -l tmp/deploy/images/qemux86-64/*.spdx.*
    core-image-minimal-qemux86-64.spdx.json
    core-image-minimal-qemux86-64.spdx.tar.zst
    core-image-minimal-qemux86-64.spdx.index.json
```

Index file that lists all of the SPDX JSON files in the SPDX archive

SPDX Archive Contents

```
$ tar -tvf core-image-minimal-qemux86-64.spdx.tar.zst
    core-image-minimal-qemux86-64-20220614012543.spdx.json
    util-linux-lsblk.spdx.json
    runtime-util-linux-lsblk.spdx.json
    util-linux-unshare.spdx.json
    runtime-util-linux-unshare.spdx.json
    recipe-util-linux.spdx.json
    ...
    index.json
```

SPDX Archive Contents

```
$ tar -tvf core-image-minimal-qemux86-64.spdx.tar.zst
    core-image-minimal-qemux86-64-20220614012543.spdx.json
    util-linux-lsblk.spdx.json
    runtime-util-linux-lsblk.spdx.json
    util-linux-unshare.spdx.json
    runtime-util-linux-unshare.spdx.json
    recipe-util-linux.spdx.json
    ...
    index.json
```

Image SPDX file (from before)

SPDX Archive Contents

```
$ tar -tvf core-image-minimal-qemux86-64.spdx.tar.zst
    core-image-minimal-qemux86-64-20220614012543.spdx.json
    util-linux-lsblk.spdx.json
    runtime-util-linux-lsblk.spdx.json
    util-linux-unshare.spdx.json
    runtime-util-linux-unshare.spdx.json
    recipe-util-linux.spdx.json
    ...
    index.json
```

Archive Index file (from before)

SPDX Archive Contents

```
$ tar -tvf core-image-minimal-qemux86-64.spdx.tar.zst
    core-image-minimal-qemux86-64-20220614012543.spdx.json
    util-linux-lsblk.spdx.json
    runtime-util-linux-lsblk.spdx.json
    util-linux-unshare.spdx.json
    runtime-util-linux-unshare.spdx.json
    recipe-util-linux.spdx.json
    ...
    index.json
```

SPDX file describing packages installed in the image

SPDX Archive Contents

```
$ tar -tvf core-image-minimal-qemux86-64.spdx.tar.zst
    core-image-minimal-qemux86-64-20220614012543.spdx.json
    util-linux-lsblk.spdx.json
    runtime-util-linux-lsblk.spdx.json
    util-linux-unshare.spdx.json
    runtime-util-linux-unshare.spdx.json
    recipe-util-linux.spdx.json
    ...
    index.json
```

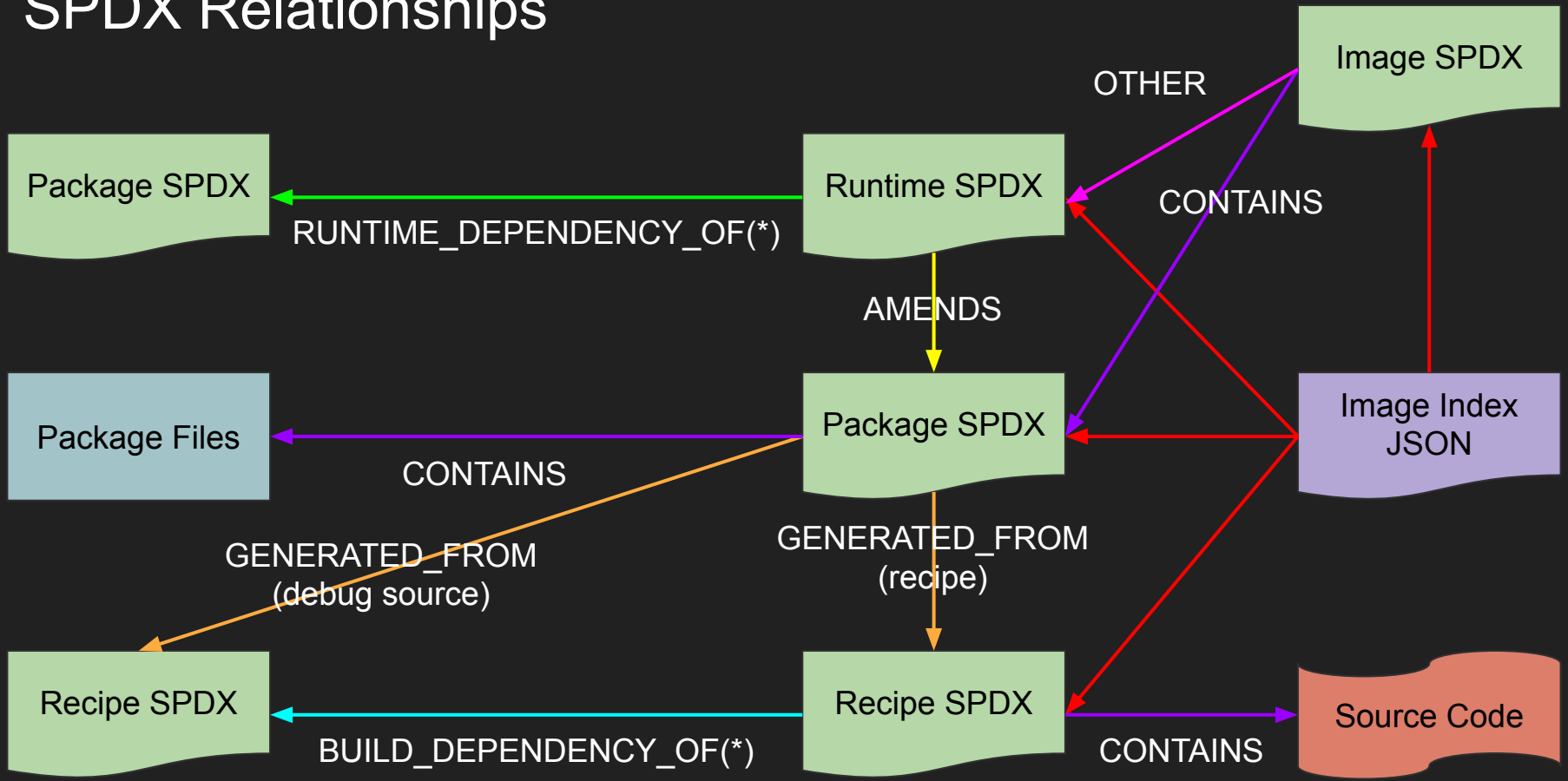
SPDX file describing runtime dependencies of packages installed in the image

SPDX Archive Contents

```
$ tar -tvf core-image-minimal-qemux86-64.spdx.tar.zst
    core-image-minimal-qemux86-64-20220614012543.spdx.json
    util-linux-lsblk.spdx.json
    runtime-util-linux-lsblk.spdx.json
    util-linux-unshare.spdx.json
    runtime-util-linux-unshare.spdx.json
    recipe-util-linux.spdx.json
    ...
    index.json
```

SPDX file describing the recipe and source code used to generate packages

SPDX Relationships



Future Improvements

- Improve Relationships (in talks with upstream SPDX)
- Pull in SPDX/SBoM from upstream source code (e.g. reuse)
- More SPDX fields
- Include information about how recipes are built (e.g. CFLAGS, etc.)

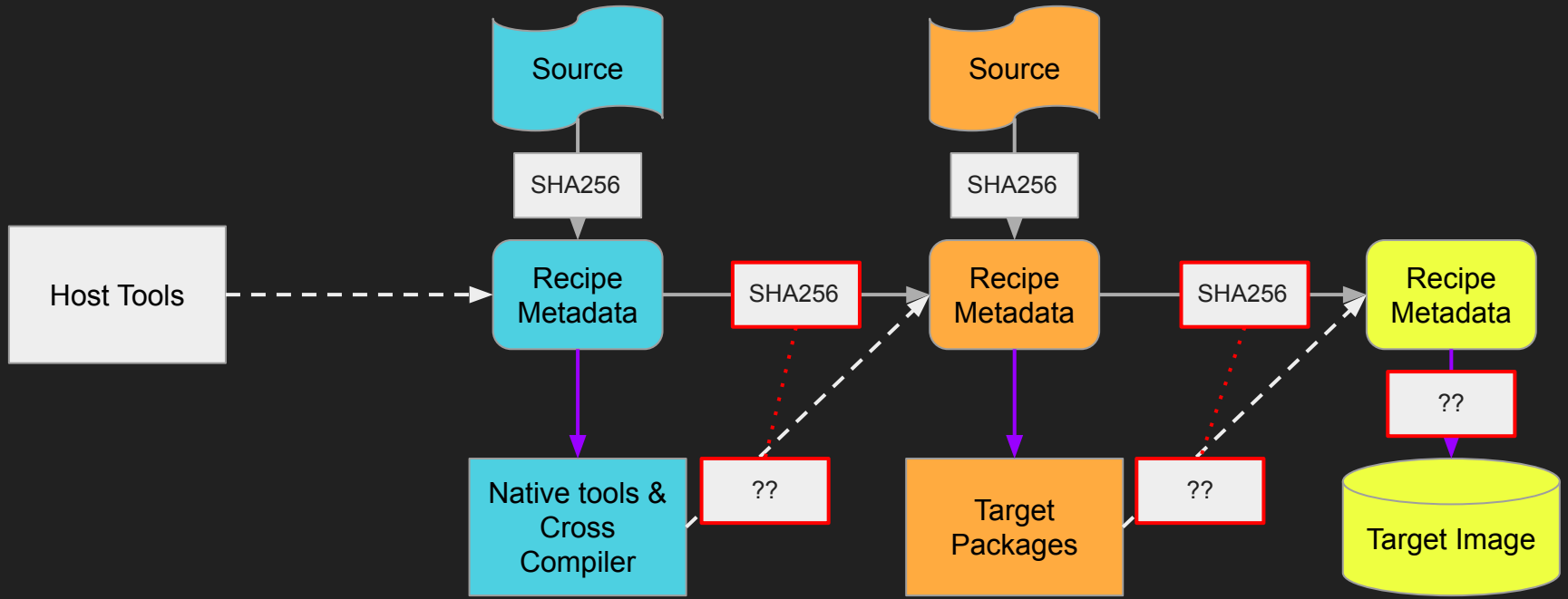
Reproducible Builds

Why do we need reproducible builds?

- Resist attack
  - What binaries need more scrutiny?
- Compiler Trust
  - Diverse Double-Compilation (David A. Wheeler) requires reproducible builds
- Quality Assurance
  - Rare timing bugs, race conditions, locale dependencies
- Smaller Binary Differences
  - Better delta updates
- Increased Development Speed
  - No need to rebuild if nothing has changed

https://reproducible-builds.org/docs/buy-in/

Binary output should associate with recipe hashes



Reproducibility Testing

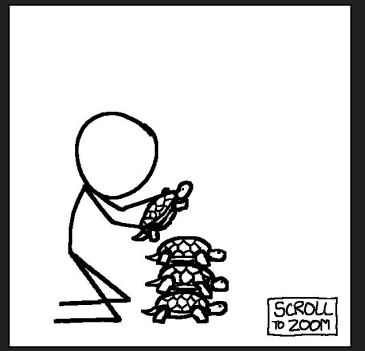
- Yocto Autobuilder tests regularly for regressions
- https://www.yoctoproject.org/reproducible-build-results/
- ~11,000 *target* packages
- 3 Package formats (ipk, deb, rpm)
- Multiple build hosts (Fedora, Ubuntu, CentOS, Debian)
  - Ensures cross-host builds are reproducible!
- Automatic diffoscope HTML output for packages that are not reproducible

Extending Quality Assurance Test

- The QA test for reproducibility is designed to be easy to extend and run for testing your own images:

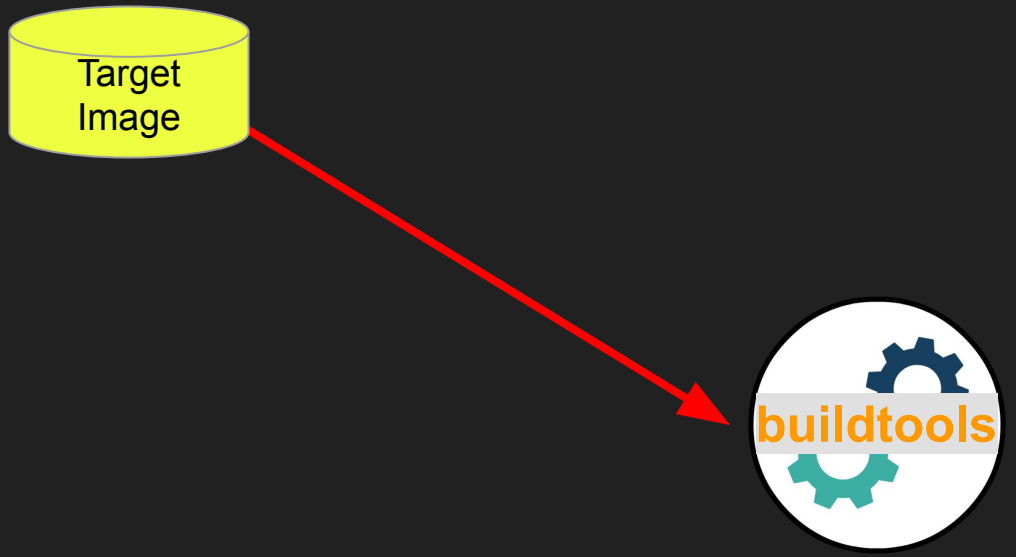
```
$ cat lib/oeqa/selftest/cases/myreproducible.py
from oeqa.selftest.cases.reproducible import ReproducibleTests

class MyReproTests(ReproducibleTests):
    images = [‘my-image’]



$ oe-selftest -r myreproducible
```

Buildtools Tarball
"It's SBoMs all the way down"

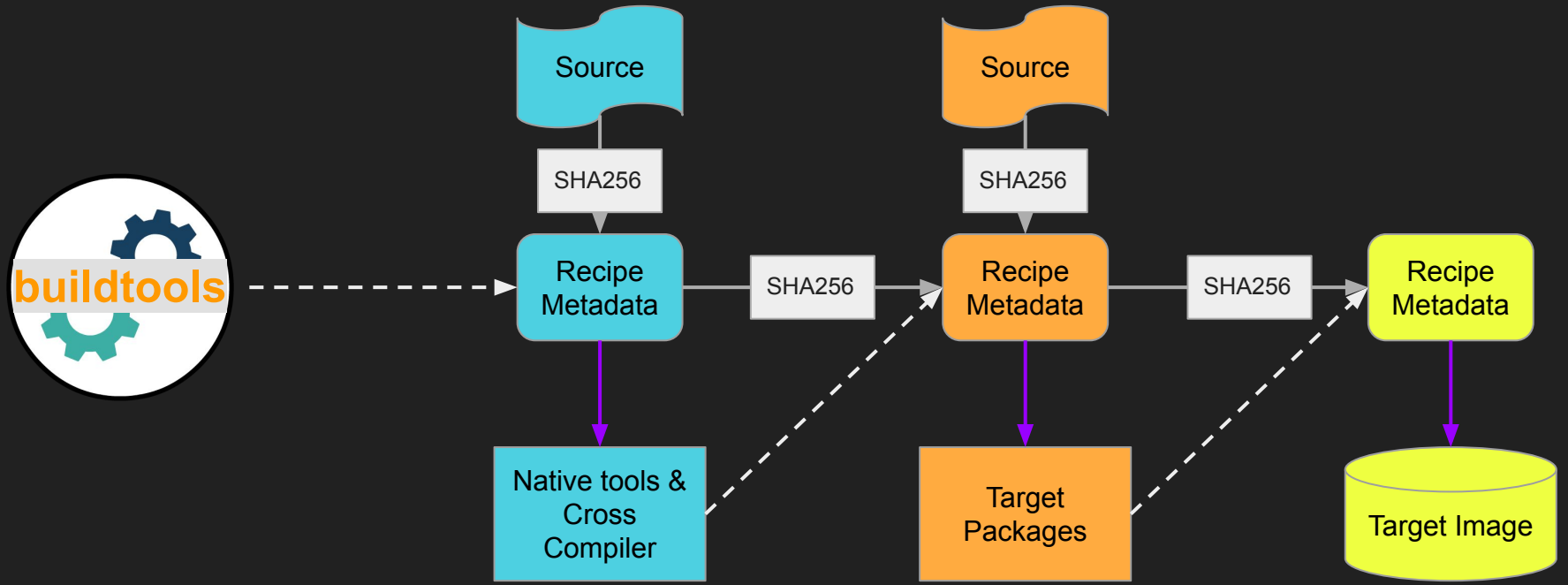


xkcd.com

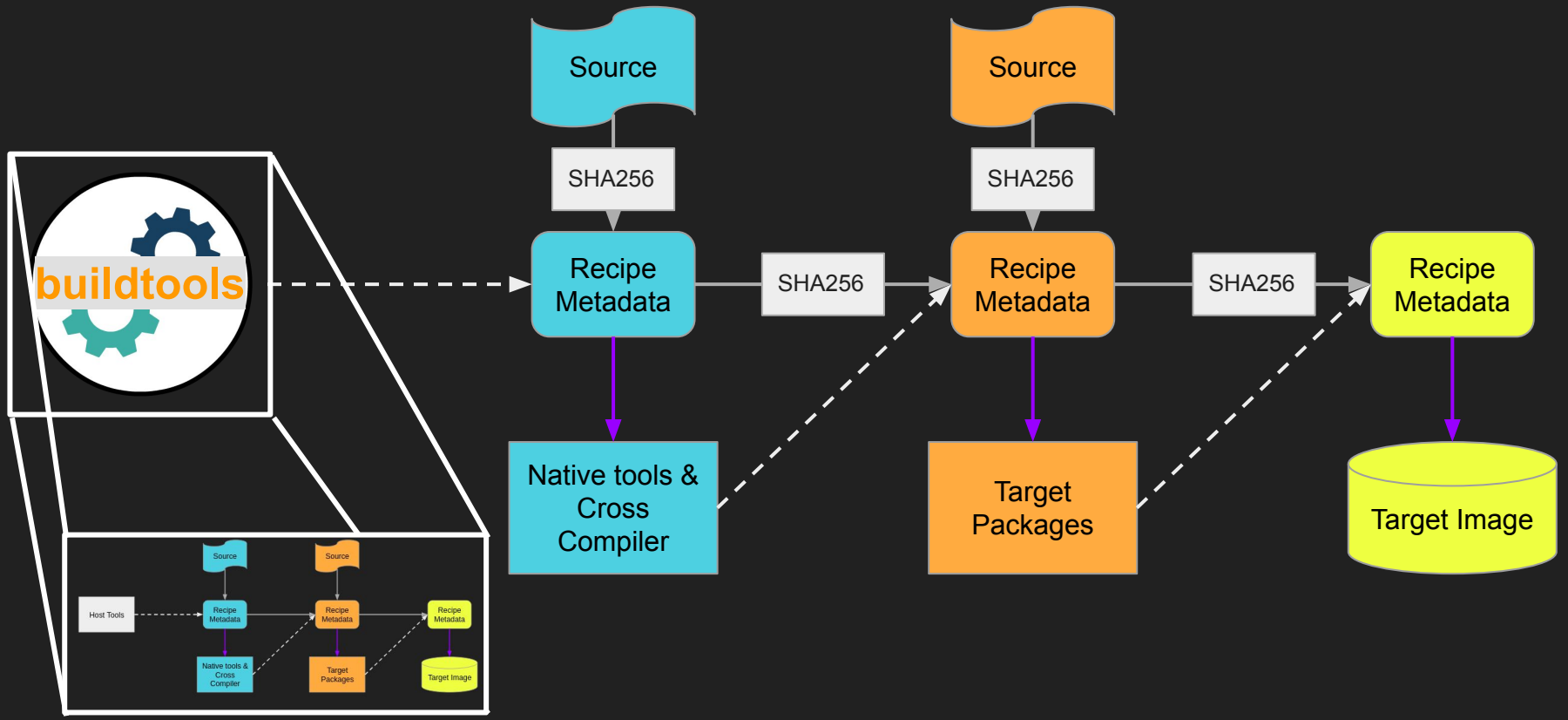
Images



Buildtools replaces Host tools



Buildtools replaces Host tools



Special Thanks

- Saul Wold (Linux Kernel SPDX Generation)
- Ross Burton (License Work)
- Andres Beltran (SDK Support)
- Richard Purdie (Yocto Project Technical Lead)
- Many others for various fixes & improvements!

Getting Involved

- Libera IRC
  - #yocto
  - #oe
- Weekly technical meeting
  - Every Tuesday at 8:00 AM Pacific Time
- Weekly Bug Triage
  - Every Thursday at 7:30 AM Pacific Time
- Happy Hour
  - Last Wednesday of every Month (Calendar)
- Yocto Project Summit
  - Twice yearly

Questions?